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Inspection Station Allocation in the Production Line by Simulation: A Case Study

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Abstract

This paper is an attempt to help a company to understand the effect of inspection station allocation in the production line and the effects on the production time. An attempt to reduce the number of the inspection station will be done as a proposed method to reduce the production time. The company has adopted accept defect and repair inspection policy and this policy should never be violated. The production line is first being analyzed in response to complaint through computer simulation. After that, the researcher tried different alternatives in the attempt to seek for the possible improvement in the layout or arrangement in the production line in regard of the inspection station allocation. The effect of different inspection station allocation layout is then being evaluated on the production time. After reducing the number of inspection station, interesting enough, the production time does not seem to decrease but increased. This finding contradicts the conventional thought of fewer stations means shorter time. This finding could help the managerial line of the company to understand the change that might take place and might help them making a better decision. This is also very helpful in real life practice in company as to help them improve their production time.

Keywords: *Production line, Inspection, ProModel.*

1. INTRODUCTION

According to [1], manufacturing can be defined in two ways, one technologically, and the other one economically. Manufacturing in the technological term means the application of physical and chemical processes to alter the geometry, properties, or appearance of a given starting material to make parts or products. In the economic term, manufacturing means, the transformation of materials into items of greater value by means of one or more processing operations. In easy words, manufacturing adds value to the material by changing its shape or properties, or by combining it with other materials that have been similarly altered.

Basically, this process is not as easy as it seems. A lot of problems could occur during this process which requires a lot of preparation and consideration so that everything will run as it should be. Two main method can be done to achieve this desire, one through the rigorous on the floor tests combined with mathematical problem solving, and the other one through simulation by the aid of computer software which will give the prediction on how well the whole or partly processes of manufacturing could be done to be compared with the real one.

1.1 Background of Study

Manufacturing has become part of all human activity since a long time ago until it is quite impossible to track back when all of this whole process started. This is because, human body itself is a very complex system which produces a lot of things such as voice, movement, idea to create a book, journal and the list seems endless. If we really want to establish this entire event, we must find the first human or creature that live in this world. But the problem is, after centuries, scientist kept finding the older human body than the previous finding.

On a focused manner, the history of manufacturing can be separated into two subjects. The first one is man's discovery and invention of materials and processes to make things, while the second one is the development of the systems of production. The event of human discovery to invent materials and processes to make things started several millennia ago. Some of the processes are the casting process, hammering (forging), and grinding which dated back more than 6000 years ago [1]. For this research paper, the focus is towards the possible improvement in the production systems and how to increase the productivity. Thus, an efficient production line design as part of a manufacturing system is a vital problem for some companies [2].

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1.2 Problem Statement

"The possible permutations and combinations of work pieces, tools, pallets, transportation vehicles, transport routes, operations, etc., and their resulting performance, are almost endless. Computer simulation has become an absolute necessity in the design of practical systems, and trend towards broadening its capabilities is continuing as system move to encompass more and more of the factory". [3].

In the selected research place, the company wants to improve and increase its production capacity, quality, and net profit. According to their experience, they do not have any bottleneck on the production and procurement part of the manufacturing. They are having problems in the recently developed production line for a new product requested by their customer. Based on the experience of the worker, some steps could be combined but never be skipped such in the many steps of inspection. They never really test this in reality and wish to see how it will impact on the production time. This has attracted the attention of the manager in charge and the researcher of the affect of this action on the production time. For this reason, they have decided to explore a number of scenarios to help in this problem. They also stipulate the following

- the solution must not require high investment and technology;
- the solution must follow the inspection policy of the acceptance of the defective units which requires repairing of the defective units after detection;
- solution must not require highly skill workers (they should be trained in a few working days);
- the process or steps in the production of the product cannot be skipped but can be combined.

The above idea suggests that there is a need for a simulation technology in order to overcome the manufacturing problem. Basically there are two ways in accomplishing this objective. The first method is by field measurement which is costly and time consuming. While the second method is through computer simulation which had been mentioned and proposed in the above statement. It also could be derived that the application of simulation being even broader, relevant and practical as the time passes by suitable with the technological change that continuously happen. Simulation is considered as an increasingly important computer aid to the design process, partly because of the growing complexity of manufacturing systems, and partly because of their dynamic and stochastic behaviour [4];[5];[6];[7]. Simulation is one type of modelling, and it offers many benefits including in the manufacturing system and production line [8]; [9]; [10].

1.3 Objective

1 To evaluate the impact of different inspection station allocation on the production time through the usage of computer simulation within the scope of acceptance of defective units and repair policy.
2 Help the managerial line of the related company to better understand the system first before and after change in order to make a better decision for the company.

2. RELATED WORKS

2.1 Production line definition

"Production line is a series of arranged workstations so that the product moves from one station to the next, and at each location a portion of the total work is performed on it [1]." This is where the materials available in the manufacturing system being processed and joined together to create a product which could be neither finished product nor half finished product which will be supplied for another process. Basically there are two main types of production line. The first type of production line is where every product is identical. As an example is the production line to produce a car, there is only one type of window, one type of door, one type of tyre and so on to produce a single type of car.

While the second type of production line is the mixed-model production line. This type of production line applies to the situations where there is soft variety in the product made on the line. Modern automobile is an example, where there are many types of car body, door, tyre and so on to produce many types of cars. Cars coming off this production line have variations in options and trim representing different models and in many cases different nameplates of the same basic car design.

From those two types of production lines, according to [11], there are several flow patterns or design of the production line. The first type is the single product flow pattern. The second pattern is the semi-parallel product flow pattern, and the last pattern is the parallel product flow pattern.

Flow lines, of which, production lines are an example is the most commonly used system in a mass production environment. Production lines enable the processing of complex products by workers who have received a short training period [12]. Thus, an efficient production line design as part of a manufacturing system is a vital problem for some companies.

2.2 Relevant Literature on Inspection Allocation in the Production Line

2.2.1Inspection Allocation in Serial Multistage Production Systems

[13] were the first to formulate the problem of inspection allocation in serial production systems. The problem is solved minimizing an objective function which accounts for inspection, lost production and quality loss costs. Every step of the production system has a known probability of generating a defect and the quality tests are available after each processing stage. The defective parts are removed from the production system. [14], besides the variable inspection cost, introduced the fixed cost as quota of the amortisation and they made the assignation of tests depend upon the history of the piece, which is the sequence of operations previously assigned. [15] proposed the first model that considers two types of inspection errors: acceptance of defective units and rejection of conforming parts.

The analysis of inspection allocation in multistage production system has been gradually refined and several contributions on this issue were proposed loosening some of the original hypothesis and proposing different solution methods. [16] studied the impact of inspection errors on the final solution and demonstrated that type I errors (rejection of conforming parts) have a greater effect than type two errors (acceptance of defective units). [17] developed the first model to account for non-conformity costs that vary according to the stage where the nonconformity has appeared. [18] proposed a model that permits to consider different management policies for defective units that can be either repaired, replaced, reworked or discarded with costs that vary according to the stage in the manufacturing process. Considering that multiple or repeated inspections can be a way to limit the effects of inspection errors, [19] proposed a non-linear integer programming model for an integrated approach to sequencing and locating multiple inspection operations which distinguishes itself for the presence of a transfer function that links incoming and outgoing level of quality and costs for each testing and manufacturing operation. [20] proposed a model that considers the presence of several parts, each one having a different technological cycle defined through the sequence according to which they have been worked on every machine.

This model is characterized by the fact that a constraint on the maximum time for the availability of inspection machines is set. [21] formulated a model based on the finite inspection resource constraint and an inspection error model: the inspection error is not constant or a specified probability, but accounts for inspection capability, manufacturing capability and tolerance. [22] presented a heuristic to solve the inspection allocation planning problem with two types of workstation, workstation of attributable data (WAD) and workstation on variable data; in addition this study considers three possibilities for the treatment of detected nonconforming units, namely repair, rework and scrap.

2.2.2Inspection allocation in non-serial multistage production systems

[23] was the first one to consider non-serial systems: in his model, that finds the best solution minimizing the internal and external cost of quality and the inspection cost, every operation has a defined probability of generating a defective unit, a perfect test is available after every operation and reparation is perfect as well. Following a path similar to the one described for serial production systems, the models proposed for inspection allocation in non-serial multistage production systems have been gradually refined.

[18]developed Brytney's model by introducing first type and second type inspection error. [24], taking into account the reduction in inspection error thanks to repeated inspection, developed a dynamic programming model having as variables the position of inspections and the number of repetitions (defined as inspection degree). Also for non-serial system, [25] considered the problem of allocating both manufacturing and inspection operations whose relative job order is not assigned beforehand but defined through precedence relations defined in an assembly diagram. The probabilities to generate 6 defective units are known but depend upon the specific operation and the operations previously assigned; I type and II type inspection error are considered and defective parts are discarded.

2.2.3Summary

From the work of previous researcher, one could see that the problem of selecting a suitable or proper inspection step and integrate it into the production line is really important. It will affect the result or output from the production line. It is also evident that the issue of inspection and production line should be addressed as it affects the production of the company.

3 METHODOLOGY

This study is using action research method that is descriptive and makes the research quantitatively. In this study, researcher would use observation and data collection from the present result and available previously recorded data.

3.1 Methodology flow chart

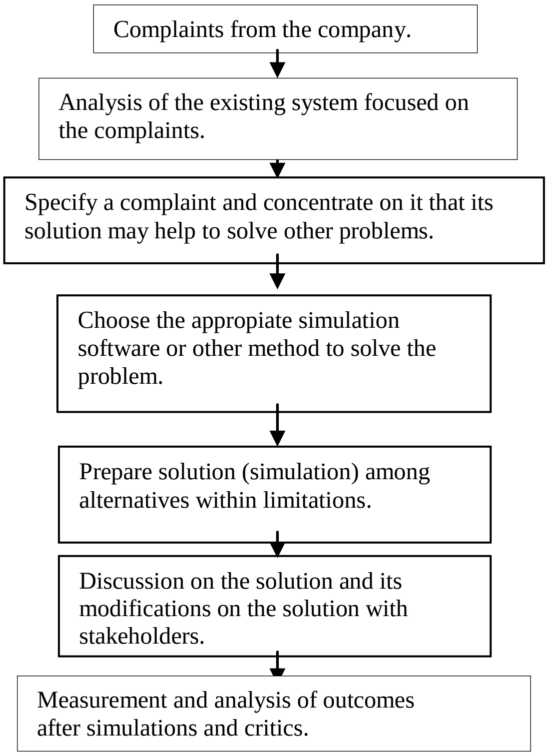

Figure 1: Structured approach for using simulation as an innovation.

This structured approach can be explained as follows; box 1 is for complaints, box 2 represents analysis of complaints for the existing system, box 3 identifies a complaint and focuses on its solution, box 4 is for choosing the right simulation software or method, box 5 is for alternatives considering limitations, box 6 discusses the solution and modifications with stakeholders, box 7 is for measurement of outcomes.

4 RESULTS & ANALYSIS

Table 1: Result comparison between different inspection station allocations

Scenario	Duration	Time (hours and minutes)
original	9.35	9 hours 21 minutes
no inspection	7.57	7 hours 34.2 minutes
inspection at the assembly and finishing line only	8.49	8 hours 29.4 minutes
shared inspection initial and last	9.69	9 hours 41.4 minutes
shared inspection	9.69	9 hours 41.4 minutes
inspection at the end of line	9.7	9 hours 42 minutes
shared only one inspection	9.77	9 hours 46.2 minutes

The above table show the comparison between the results in term of production time of the different alternative in determining the inspection policy station as applying the accept reject inspection policy. The result for the current layout of the production line has resulted in 9.35 hours of production time in finishing the batch of 50 inputs. In order to know how the production system operates and react in term of the production time without a single inspection station, the researcher has removed all of the inspection station. This is due to the fact that one could not simply deduct the total production time for 50 inputs with the total amount of time available for all of the inspection stations regarding the dynamic effect of the production line.

A simple mathematical approach as such is futile in describing a dynamic and quite complex nature of the production line of this factory or any other and this is another reason why simulation is such a handy helping tool in such a situation. This has resulted in 7.57 hours of production time as compared to 9.35 hours in the current layout. The difference of 1.78 hours or 1 hour and 46.8 minutes just to inspect seems insignificant since inspection process is a non value added process but rather a mechanism of controlling quality. Since the extensive measure of inspection has undertaken in the two earlier lines which is the fixed blade and moving blade production line, it is wise to see how much time being spent just to do the inspection in these two lines since after each process the company will inspects the items. The whole production line operates in 8.49

hours if all of the inspection stations in these two lines being removed. This mean that the inspection process being taken in these lines is 51 minutes and 36 seconds combined which is long.

Since the subsequent lines after these two lines is the assembly and finishing line with only one inspection station in each line respectively, it is impossible to remove the inspection step in both of these subsequent line as it will jeopardize the quality and output of the end product all together. Due to that fact, some changes has to be taken in term of the inspection station allocation as it forms nearly half of the stations in the fixed and moving blade production line. As an example, the total station for the fixed blade production line is 7. Out of 7, there are four stations just for inspections. More stations mean more work. More work will definitely require more time to do it and not to mention the extra cost that a company or factory like this try their best to avoid. Due to some restriction, the issue regarding the cost could not be mentioned in this paper. Then, the researcher will only focus on the time taken to do the work and how much output can be produced in that amount of time.

By taking the above fact into account a few allowable possible scenarios or alternative has been proposed to see how the production line would react towards different combination or rearrangement of the inspection station. The allowable term is applicable since the factory has requested and set certain rule as to change the rearrangement of the production line to meet the customers' demand. This term has been stated clearly in chapter one.

The first change is to remove all of the inspection stations in the fixed and moving production line and replace it with a single inspection station at the end of both lines. This station also has to be shared by both lines. The same also being applied to the assembly and finishing line, they will share a single inspection station. The inspection in these two lines will be served in this one station according to their respective process and timing. The only different between this shared in this inspection station is, the first one for the fixed and moving blade is not fully manual and being assisted with a laptop being attached to the inspection tool with minimal human involvement with a standardized procedure and timing. It will check all aspect of inspection at one shot. The reading and detection of the error is being checked automatically. The second shared inspection which serves the assembly and the finishing line is a manual inspection station and the timing will change accordingly to the inspection process.

For this scenario or modification, the resulting production time is 9 hours and 41.4 minutes which shockingly more than the original layout which is 9 hours 21 minutes even with the reduction of inspection station to only two instead of nine stations all over. The increase in the production time is quite unexpected due to the reduction of the inspection station subsequently the process itself. In simple mathematic and assumption, this would expectedly produce a shorter production time. But that obviously not the case in the dynamic nature of a production line where a simple mathematical calculation is not enough and a complex algorithm is a suitable assistant. That is the case if the researcher has a strong mathematical background, but a simulation is or simulator is easier for someone in the area of management to incorporate in decision making, like this research.

The increase by 20.4 minutes of production time might be due to the exhaustion of the shared inspection station for the fixed and moving blade. These lines operates side by side at the same time making it possible that either one of the item in the line have to wait due shared process of inspection. This is true since as much 44.17% or 22 items of the moving blade have to wait before being processed and 2.47% or 1 item is being blocked while the remaining balances in processing. This does not happen in the fixed blade line as there is no blocked or waited item in the line. This for sure has increased the processing time in the moving blade line and the resulting whole production time as for the assembly process, both the fixed and moving blade has to be present in order to assemble both of it which results in some more time for waiting. Back to the second objective of the research which is finding the best inspection allocation in the acceptance of defective units inspection policy or environment being implemented in the factory. This scenario does not suit the second objective as it results in more production time instead of the reduced work station or inspection station.

The same situation does not appear to befall on the assembly line and the finishing line because even with a shared inspection station, the step for inspection took place at different time and sequent since the assembly process have to be done first then the finishing process will follow.

In the second scenario, the fixed and moving blade still has to share the same inspection station as the previous scenario. The only change that takes place this time is the assembly and finishing line does not share the same inspection station as the preceding one as a total there are three inspection stations in this scenario. The resulting production time is maintained at 9.69 hours or 9 hours and 41.4 minutes. This does seem to support the explanation in the scenario where the additional 20.4 minutes in the production time occurred due to the waiting item in the moving blade line which disrupts the following processes. As to further prove it, even with the addition of one more inspection station in the assembly and finishing line, which they no longer share the same inspection station, the resulting product time does not seem to be altered at all with this change. It rather appears clear that the cause of the additional production time exist in the line before it which is the fixed and moving blade line.

The third scenario where the inspection stations are made available in each line, one for fixed blade, moving blade, assembly and finishing line has resulted in 9.7 hours or 9 hours and 42 minutes of production time. Even with one more addition of the inspection station, making the total inspection stations in existence in the production line is four, the production time does not seem to increase significantly. The different of only 0.6 minutes or 36 seconds from both the previous scenario does not seem to bother in this kind of situation but in other more critical situation it might, such as before the explosion of a bomb.

After increasing the number of inspection station from just two up to four stations and the production time seems not increase, and seem quite constant with the result which is higher than the original, the last scenario is to test what will happen if only one inspection station available and being shared by the four lines. This change has resulted in 9 hours and 46.2 minutes of the production time. That means an increase by 25.2 minutes from the original layout and an increase by 4.8

minutes from the rest of the tested possible inspection layout. Even with the reduction of the inspection station up until one, the production time seems does not react in a positive way which means the decrease in the production time.

5 CONCLUSION

As a conclusion, after testing with a few different layouts in allocating the inspection station in the hope of decreasing the production time presumably, it does not help. In fact, the production time increases with the reduction of the inspection station. Furthermore this research proves that simulation software is helpful in testing possible changes in a manufacturing system or in this case particularly the production line. It helps the managerial line to better understand and most probably make a calculation of future profit or loss due to the change. Understanding of the system would be costly and almost impossible without a field test prior the usage of this software in the related company.

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